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Energy Efficient MIMO-Based IoT Networks: An Overview

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Abstract : An array of specialized objects, referred to as things, are utilized to gather, manage, to share real-time information across the Internet and other networking. This network is known as the Internet of Things (IoT). Each object in the IoT holds a unique ID for authentication when it is linked to the network or web. A number of issues can be overcome in order to accomplish it, including those related to technological interactivity, data integrity and privacy necessity, as well as the creation of an energy-efficient operational network. A lot of IoT systems are starting to use cellular-based IoT backend having MIMO functionality because of its wide area of coverage as well as rapid speed. The primary focus of the research presented here on the differences in routing algorithms from a basic IoT network to a MIMO-based network is on how both types of networks manage communication, particularly with regard to transmission of data across devices. It also takes a look at how the growing IoT applications relate to the IoT network standards as well. While waiting for better capacity across a multi-path channel scenario, numerous Internet of Things applications have to use multiple-input multiple-output (MIMO) technology in order to support fifth-gen (5G) communications. The ability of IoT sensors to gather or harvest energy determines how reliable and efficient network connectivity is inside the Internet of Things. To meet computing demands, it's becoming crucial to manage energy sources effectively. This will guarantee IoT sensor continual operation along with maximum efficiency for a variety of uses. The main points of MIMO-based Internet of Things networks are provided in this research. It assists to identify the issues that have yet to be addressed, clearly defines the current state of research. study has been undertaken to investigate the determinants of stock returns in Karachi Stock Exchange (KSE) using two assets.

***Index Terms* - Energy Efficiency, Internet of Things, IoT applications, Routing protocol.**

I. INTRODUCTION

The term "Internet of Things" (IoT) describes the upcoming stage of the Internet's development, which includes a networked architecture that links a lot of objects so they may exchange information and gather data in order to make intelligent choices [1]. It's imperative to remember that within this context, "devices" refers to any kind of objects that has been integrated with the hardware or software required to enable communications as well as computation. The smart city can save resource spending and energy expenditures with intelligent solutions. Mobility, medical services, energy, education, or many other applications of smart cities (SCAs) can all benefit from their improved performance plus operational management. Recent innovations underpinning the concept of smart cities offer a range of smart solutions. The Internet of Things (IoT), robots, cloud-based computing (ClCom), Foggy Computing (FoC), wireless sensing networks (WSNs), cyber or computerized physical systems (CPS), with huge-scale data processing are a few scenarios involving these innovations. IoT, which has many positive effects on everyday life, is the main technology utilized in smart city projects [2]. In order to improve its adoption as well as usage, IoT technology must overcome numerous assurances, efficiency, along with confidentiality challenges that arise from its rapid growth [3]. The increased accessibility of all objects or sensor devices-which additionally calls for an identification management system-depends on the IoT being standardized. Significant challenges are also raised by privacy along network safety [4]. It is imperative to have effective energy plus information control mechanisms in order to green the Internet of Things. Each of these issues must be handled in accordance with the form of networking that has been chosen.

Network coverage has been shown to be a more relevant parameter for assessing the quality of services (QoSs) of IoT networks, as opposed to the standard concept of IoT network lifespan, which takes into account factors like battery life [5]. When evaluating QoSs along Quality of User Experience (QoE) for IoT applications, the network's coverage is more significant than the network's lifespan. As the industry standard, 5G, or fifth-gen, mobile networks can support the growth of IoT devices meanwhile upholding the necessary QoSs. Multiple-input multiple-output (MIMO), one of possible 5G facilitators, can further enhance efficiency, lower transmission consumption of energy, thus increase the attractiveness of the network to IoT applications [6]. But these wireless sensor nodes are limited in terms of memory, processing, as well energy-constrained devices [7]. This has proven to be one of the main issues with WSNs or their apps. Afterwards, the following categories can be used to distinguish between a simple IoT network versus a MIMO-based IoT network:

Routing Protocols: Routing protocols are meant to create channels of communication between devices in a basic or simple IoT network. Simple IoT networks often employ the following routing protocols, such as

RPL (Routing Protocol for Low-Power and Lossy Networks): A popular routing protocol for low-power and lossy networks—features common to many IoT deployments—is RPL. Its goal is to maximize energy efficiency while adjusting to shifting network circumstances.

6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks): IPv6 packets may be transmitted via low-power, low-rate wireless networks thanks to the 6LoWPAN protocol, which is appropriate for a wide range of Internet of Things applications [8].

On the other hand, MIMO technology, which uses multiple antennas for transmitting and receiving, mainly affects the physical layer of communication. The routing techniques utilized in basic IoT networks are still applicable in MIMO-based networks. Routing protocol selection is increasingly dependent on the properties of the network, including lossy communication, low power consumption, dynamic condition adaptation, and effective routing in resource-constrained environments.

Topology: Star or mesh topologies are common in simple IoT networks. Devices connect directly to a central hub or gateway when using a star architecture. Devices may communicate with one another in a mesh topology, creating a more dispersed network.

However, by employing several antennas to increase data speeds, dependability, and spatial diversity, MIMO technology improves the capabilities of the physical layer. Even so, it doesn't actually affect the device connectivity or network structure. MIMO is compatible with a number of network topologies, including as mesh and star configurations.

When transmitting and receiving, multiple antennas are used instead of a single one in multiple-input multiple-output (MIMO) devices. MIMO communication can guarantee increased data throughput while significantly boost network efficiency. The utilization of low-cost, low-power elements, decreased latency, an improved media access control (MAC) layer, with resilience to jamming are other advantages of MIMO [9]. Furthermore, it is possible to assist numerous users effectively. MIMO techniques provide a viable way to increase data transfer rates without increasing power or bandwidth. With its ability to provide reliable communication, this technology has emerged as an innovator in the groundbreaking improvements made in the wireless sector. By using this, wide coverage as well reduction in multipath loss can be achieved.

II. LITERARY WORK REVIEWS: A CLASSIFICATION

The classification of research reviews is discussed in this section. This overview offers a classification of research findings according to quality of services (QoSs), mobility, usage of energy, congestion, plus privacy, as seen in fig. 1. The following is a summary and review of each kind:

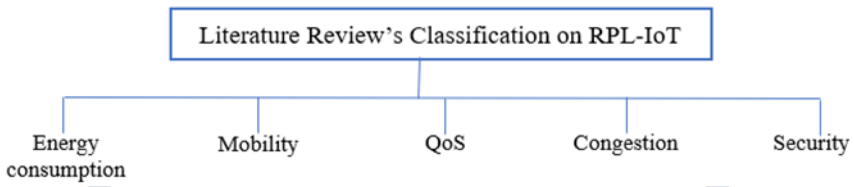

Fig. 1: Classification of RPL-IoT research reviews

2.1. Energy consumption

Low power consumption is a major concern for LLNs, which is why IEEE 802.15.4 or RPL were developed with conservation of energy as their goal [10]. Consumption of energy is used as a metric in different research that confirms this conclusion and integrates that both the number and size of nodes in the network affect how much energy is consumed. Whereas, the increase in lifespan is a result of increased throughput and transmission of energy between the network's nodes. In an effort to better the transmission of energy and increase capacity, a technique is proposed to calculate energy usage estimation that depends on radio duty cycle (RDC). A certain method that has been considered to raise RPL's efficiency of energy is to improve malfunction monitoring. Using information from less power-seeking devices, a routing and aggregating for minimum energy (RAME) approach determines where to route data within a network [11].

2.2. Mobility

Numerous research works have been done on the subject of routing for cellular or mobile WSNs, and the most recent research mainly depend on RPL, the communication protocol that is now the IoT's real-world standard [12]. RPL is further improved to support medical applications in IoT environments by Gara et al. [13], who explore RPL for hybrid networks with moving and fixed nodes. With the latest advancements in mobility management, the 'Smarter-HOP', which is a proactive algorithm, edition of mobility compliant RPL (mRPL) has been developed. A cross-layer strategy is used by mechanism. Each node's variations region is determined by the network layer using MAC layer signal strength data. The target function is incorporated to the parent selection approach of this protocol, mRPL++, to make sure that nodes have knowledge of link parameters other than received signal strength indicator (RSSI). To enhance the performance of RPL in mobile networks having dynamic characteristics, Kharrufa et al. [14] developed D-RPL for multi-hop routing for dynamical IoT applications. A 'reverse-trickle timer' called D-RPL can be activated in the event that movement is inhibited. D-RPL utilizes a few of the characteristics found in mRPL.

2.3. Quality of service

Reliability in transmitting data is a necessity for many IoT applications, and it can be attained through reducing the amount of dropped packets, increasing throughput, with lowering delays [15]. Optimizing data speeds, improving network services as well routing possibilities are all necessary to meet robust QoS standards. A cross-layered layout was proposed by Ancillotti E. et al. [16] to enhance the quality of the link estimates in RPL. It enables reliable or safe data transfer whilst consuming less energy and even dealing with fewer delays compared to initial RPL. They also propose reacting solutions that depend on the number of obtained packets of data instead of control signals to exchange information on the communication link's quality. Reference [17] presents a procedure for determining the failure of a root node in the network. The cooperative method for nodes having diverse applications for sensing is used by the approach known as Cooperative RPL (C-RPL) to minimize costs as well energy usage.

2.4. Congestion

One of the main problems regarding routing with multiple hops is congestion, which arises from the data building up over subsequent hops at a node's level [18]. There is a significant impact of congestion on energy use, reliability, along with latency [19]. For sensor nodes that do not allow application or node desired outcomes, Al-Kashoash et al. [20] provided a game-theoretic model using a dynamic data rate. To accomplish load distribution, a queue-based optimization approach was employed during which nodes exchange information about bottleneck or congestion through DIO (object of information of the DAG) packets. The parent-child transition is approached from a game-theoretic perspective, suggesting that there must be multiple pathways for data delivery, the most suitable one selected based on observations of objective functions. Whenever congestion occurs, the communication protocol makes advantage of DIO packets to allow multiple paths routing.

2.5. Security

With regard to variables like the kind of implementation, the selection of location, plus how significant the information that is being transmitted, a certain level of privacy or security is necessary for the majority of IoT operations [21]. Trustworthy, security, accessibility, reliability, or certainty are all beneficial for IoT applications. To further develop this perspective, Mayzaud et al. [22] propose an adaptable threshold criterion that changes depending on the attack type as well the network's state. It has been demonstrated that the method significantly increases the efficiency of energy. In sinkhole attacks, a node pretends to be a prominent position in order to collect information from adjacent nodes. A method for preventing fake rank ads—which are employed in such attacks—by using secured DIO packets was demonstrated. A black hole or greyhole attack in IoT refers to a type of security threat, during which malicious nodes secretly remove a portion of the data streams passing through. For the purpose of avoiding and recognizing attacks like this, it becomes imperative to use reliable communication standards, monitor network activities, as well as perform continuous technology improvements. Furthermore, access control or network division techniques might lessen the effect of a possible blackhole assault.

III. Advantages and Challenges in MIMO-based IoT Applications

Wireless communication network's functionality and efficacy have significantly improved as a result of the growth of MIMO technology [23]. Software-Defined Networking (SDN), IoT, with Artificial Intelligence (AI) are all included in the present 5G network, which also enables application-based networks along primary cutting-edge technologies [24]. The integration of SDN in IoT is an evolving field, and ongoing research and development aim to address the unique challenges posed by the diverse and dynamic nature of IoT environments, whereas the integration of AI with IoT creates a powerful synergy that enhances the capabilities of connected devices, making them more intelligent, adaptive, and responsive to user needs.

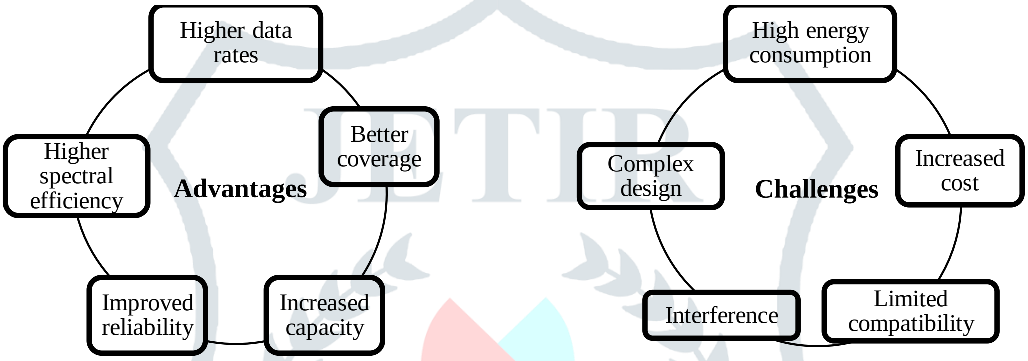

Fig. 2: Advantages and challenges in MIMO- based network

Furthermore, a number of variables, like information processing and storage requirements, the amount of data as well as time required for data transfer (including jitter, additional costs, packet loss or packet drop, and congestion), determine how much energy the devices use. Utilizing energy-effective methods or devices is crucial to lowering the use of energy while maintaining the dependability of the energy flow considering the wide-ranging nature with complexity of the IoT energy problem. The coordination and control of energy-related activities, such as generation, processing, conservation, as well utilization, are greatly aided by the IoT technologies, which also include sensors, communication systems, and also protocols [25]. The ability of widely deployed IoT sensors to harvest energy along the methods of communication they employ to do that are the primary sources of issues associated with the lifetime of IoT networks.

In order to address the above issues or challenges, scholars are continually coming up with new strategies and tactics to lower the energy usage of IoT networks as well as devices [26]. A few of these techniques consist of:

- **Energy-Efficient Protocols:** For IoT networks as well as devices to consume as little energy as possible, energy-efficient algorithms must be developed specifically for them. IoT devices have certain needs with limitations, like minimal battery life as well as low computational power, which are taken into account by these protocols [27].
- **Network-Level Optimization:** It is possible to optimize the consumption of energy of IoT networks via reducing the energy expenditure of each of the devices through the use of network-level optimization methods. As an example, these methods can reduce the quantity of data packets needed to be transmitted, which will help IoT devices use less energy [28].
- **Cloud-Based Energy Management:** Through utilizing the cloud's computing and storing capacity, cloud-based energy optimization solutions are useful for monitoring the energy usage of IoT networks. By lowering the energy expenditure of each of the devices while increasing the network's entire efficiency, this method allows for optimal energy use [29].
- **Artificial Intelligence (AI) and Machine Learning (ML)** present an exciting opportunity for tackling such issues with improving the energy-efficiency of IoT networks. For better energy generation as well transmission, power stations can benefit from the use of ML or AI techniques, which can forecast the trends of energy use of IoT sensors. Such techniques can also minimize the energy usage of IoT devices as well, which can prolong the battery's lifespan and improve the functionality of IoT networks as a whole [30].

IV. Energy-Efficient Wireless Routing Strategies and Protocols

A communication system that uses the least amount of energy possible without sacrificing dependability or functionality is called an energy-efficient or cost-effective network. The use of energy efficiently is currently an important factor in regard to information and communication technology (ICT), which involves networks as well as devices. This is because of the growing number of battery-operated together with limited resources objects, like the ones in the IoT, as well as lower expenses plus sustainability issues.

The following are important elements and tactics that go into making a network energy-efficient or cost-effective:

Low-Power Components:

- **Devices and Infrastructure:** Use energy-efficient hardware components for networking devices and infrastructure. This includes routers, switches, access points, and other network equipment designed to operate with low power consumption.

Optimized Protocols:

- **Communication Protocols:** Choose communication protocols that are designed to be energy-efficient. For example, in wireless networks, protocols like Zigbee and LoRaWAN are known for their low-power characteristics. In cellular networks, LTE-M and NB-IoT are designed for efficient communication in IoT applications.
- **Routing Protocols:** Employ routing protocols that optimize the routing of data while minimizing energy consumption. Some protocols, such as RPL (Routing Protocol for Low-Power and Lossy Networks), are designed specifically for energy-constrained environments.

Sleep Modes and Power Management:

- **Devices:** Implement sleep modes and power management features in devices to reduce energy consumption during idle periods. Devices can go into low-power states when not actively transmitting or receiving data.
- **Network Infrastructure:** Apply power management techniques to network infrastructure components. For example, routers and switches can adjust their power usage based on network traffic patterns, powering down or reducing power during periods of low activity.

Dynamic Adaptation:

- **Adaptive Configuration:** Networks can dynamically adjust their configuration based on changing conditions. For example, in wireless networks, adaptive transmission power and rate control can be used to optimize communication based on the distance between devices.
- **Load Balancing:** Distribute network traffic efficiently to avoid overloading specific components. Load balancing ensures that resources are used effectively, reducing the need for high power consumption during peak periods.

Renewable Energy Sources:

- **Power Sources:** Consider incorporating renewable energy sources, such as solar or wind power, to supply energy to network infrastructure, especially in remote or off-grid locations. This can reduce reliance on traditional power grids and decrease the environmental impact.

Network Planning and Deployment:

- **Topology Design:** Plan network topologies that minimize energy consumption. For example, in wireless sensor networks, optimal placement of nodes can reduce the energy required for data transmission.
- **Localization:** Implement localization techniques to reduce the need for devices to communicate over long distances, which can consume more energy.

Energy Monitoring and Optimization:

- **Monitoring Tools:** Employ energy monitoring tools to identify energy-intensive components and optimize their usage. This involves analysing network performance and energy consumption patterns.
- **Continuous Improvement:** Regularly assess and update the network architecture and components to take advantage of advancements in energy-efficient technologies.

A network can lower its operating expenses, lessen its negative effect on the surroundings, also increase longevity via incorporating these tactics. As a network becomes more efficient in terms of energy. With the increasing need for connectivity as well as the growing emphasis on sustainability, efficient use of energy is increasingly important with today's networking [31].

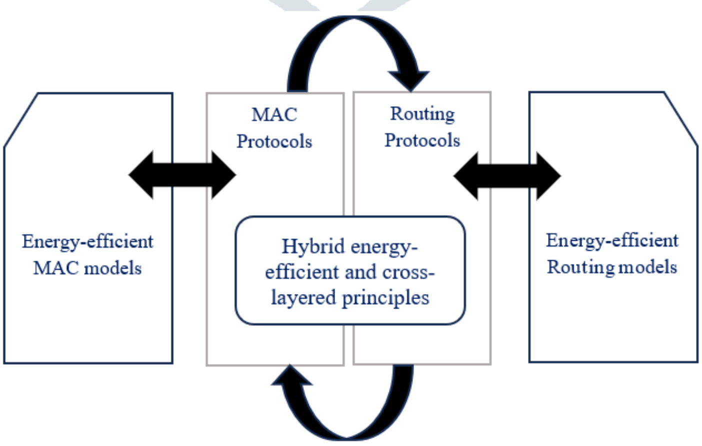

Fig. 3: Cross-layered model

WSNs lifespan is projected to be increased by established (network layer to MAC layer) or towards (MAC layer to network layer) communication, as shown in fig. 3. These methods of communication are projected to comply with its energy management concepts. In comparison with the other kinds of communication networks, it is expected that the routing algorithms developed for

IoT networks will carry out reliable data transmission with appropriate conserving energy principles. Dogra et al. [32] determined the significance of 5G IoT networks, wireless communication methods, along with energy-saving future generation systems in this way. To handle MIMO modes, future generation IoT networks must have to be dependable, scalable, and long-lasting. The formation of energy saving strategies along with 5G routing aspects to manage multiple sensors information transmission operations is the primary concern of the current research. Among the most significant technological issues in this field are the distributed load management techniques, the energy distributing fact, as and the heterogeneous network deployments.

V. Future Developments in MIMO Communication

MIMO is useful in smart city environments because it makes it easier to implement several Internet of Things uses, like smart handling trash, automated parking, including efficient lighting. It also enables greater bandwidth transmission as well precise control within a drone connection while monitoring devices [33]. Demand for faster data speeds will only increase in coming years. MIMO networks can meet this requirement by giving customers access to data speeds that might be up to ten times faster than those of 4G and 5G.

- Large-scale research for methods based on machine learning across all MIMO configurations must be conducted.
- MIMO networking systems demand a large amount of data storage and processing capacity, that might be problematic for minimal power consumption or cost-effective technologies.
- One persistent issue with optical camera communication (OCC) is rapid transmission. Despite the widespread use of mobile phones, fast speeds camera connectivity remains challenging.
- Since multiple sensors in IoT applications run under remote and battery-operated cases, efficient use of energy is important. This problem highlights how crucial it is to choose sensors that provide the required features at the lowest possible energy use.
- By reducing reliance on regular sources of energy with boosting long-term viability, the incorporation of energy collecting or harvesting energy technology within smart IoT sensor systems promotes a network that uses less energy.

VI. Conclusion

Energy usage as well as efficient data transmission techniques are undoubtedly needed as that of WSN or IoT-related uses spread globally. Furthermore, MIMO transmission has always been crucial to RF-based networking. We focused on important aspects of many networking technologies, including stability, accessibility, security, route selection, energy savings, as well connectivity for networks that are heterogeneous. This research paper examines the numerous issues related to handling energy in IoT sensors, taking into account several routing techniques, standards, along with communication systems. It is highlighted how vital it is to maintain the battery lifespan of sensors in the IoT network because energy consumption might have a substantial effect on the network's overall performance. In addition, a wide range of factors, such as the amount of data transmitted, their distance, accessibility, signal quality, dropped packets, a delay, network costs, overload, data transfer rate, plus method application, affect how much energy those networks use when transmitting information into real time. It is imperative to take into account these aspects in order to improve the efficiency as well as functioning of IoT networks, as they together influence the total energy usage of these networks. We also introduced open questions for research. Additionally, choosing protocols for network communication that give preference to cost or energy optimization in addition to providing strong encrypted data throughout communication is crucial for boosting the long-term viability or longevity of IoT systems as well networks. Lastly, we pinpoint potential research directions that might be pursued to learn more about MIMO-based communication for IoT networks as well.

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